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(54) Abstract Title
Estimation of ISSI, RSSI and SIR in a receiver

(57) A method of estimating an Interference Signal Strength Indicator (ISSI) for a finger in a receiver such as a RAKE receiver which combines signals from a plurality of antenna elements to provide a formed signal, the method comprising estimating the ISSI for the formed signal, pre-processing the ISSI estimate based on weighting factors used in the combiner to obtain an estimate of ISSI representative of ISSI for the antenna elements, filtering the ISSI estimate and post-processing the ISSI estimate based on the weighting factors to provide a filtered estimate of ISSI for the formed signal. An estimate of the total Received Signal Strength Indicator (RSSI) is calculated by coherently summing channel estimates h(i) for each finger. An estimate of th total Signal to Interference Ratio (SIR) is calculated from total RSSI and total ISSI and not from summing individual SIRs for each finger. Total ISSI is calculated as a function of individual ISSIs for each finger.

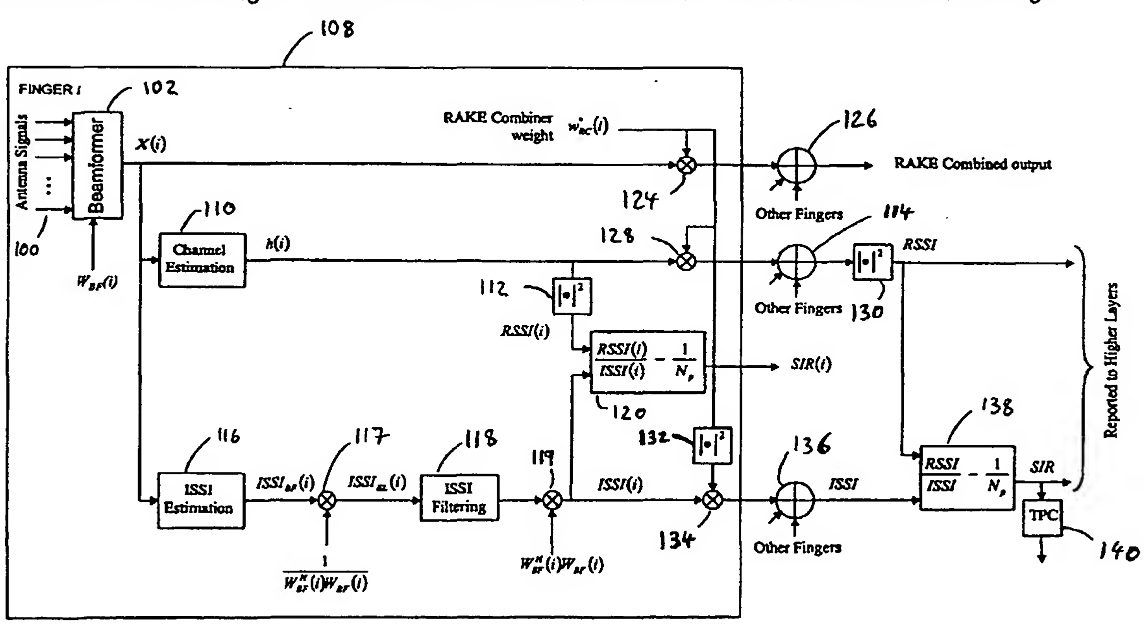

FIG. 2

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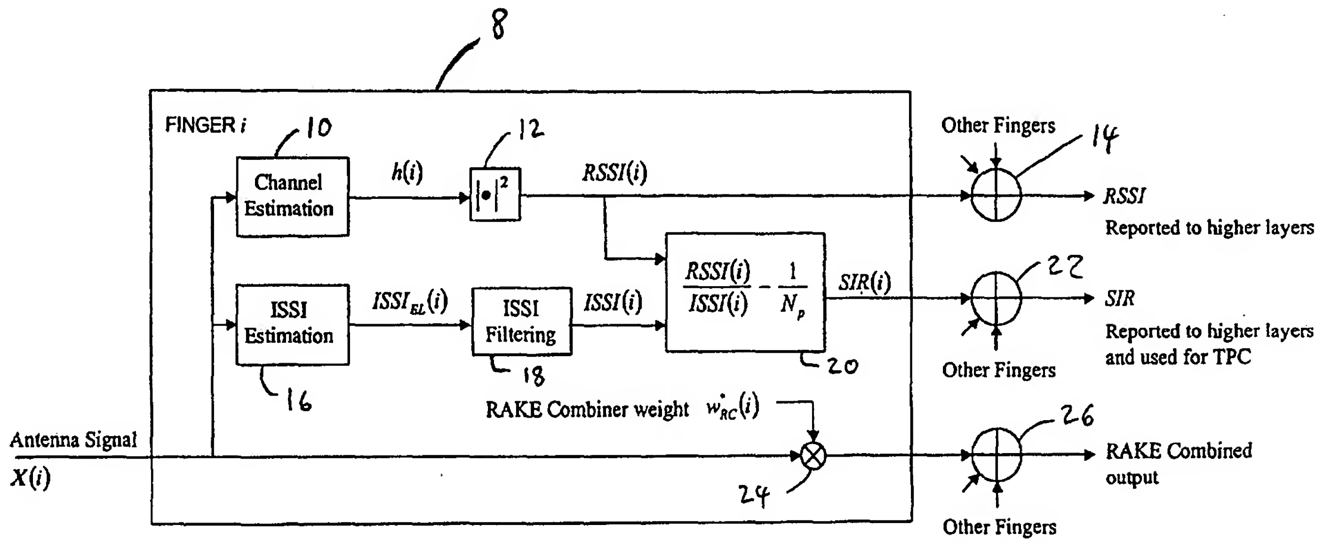
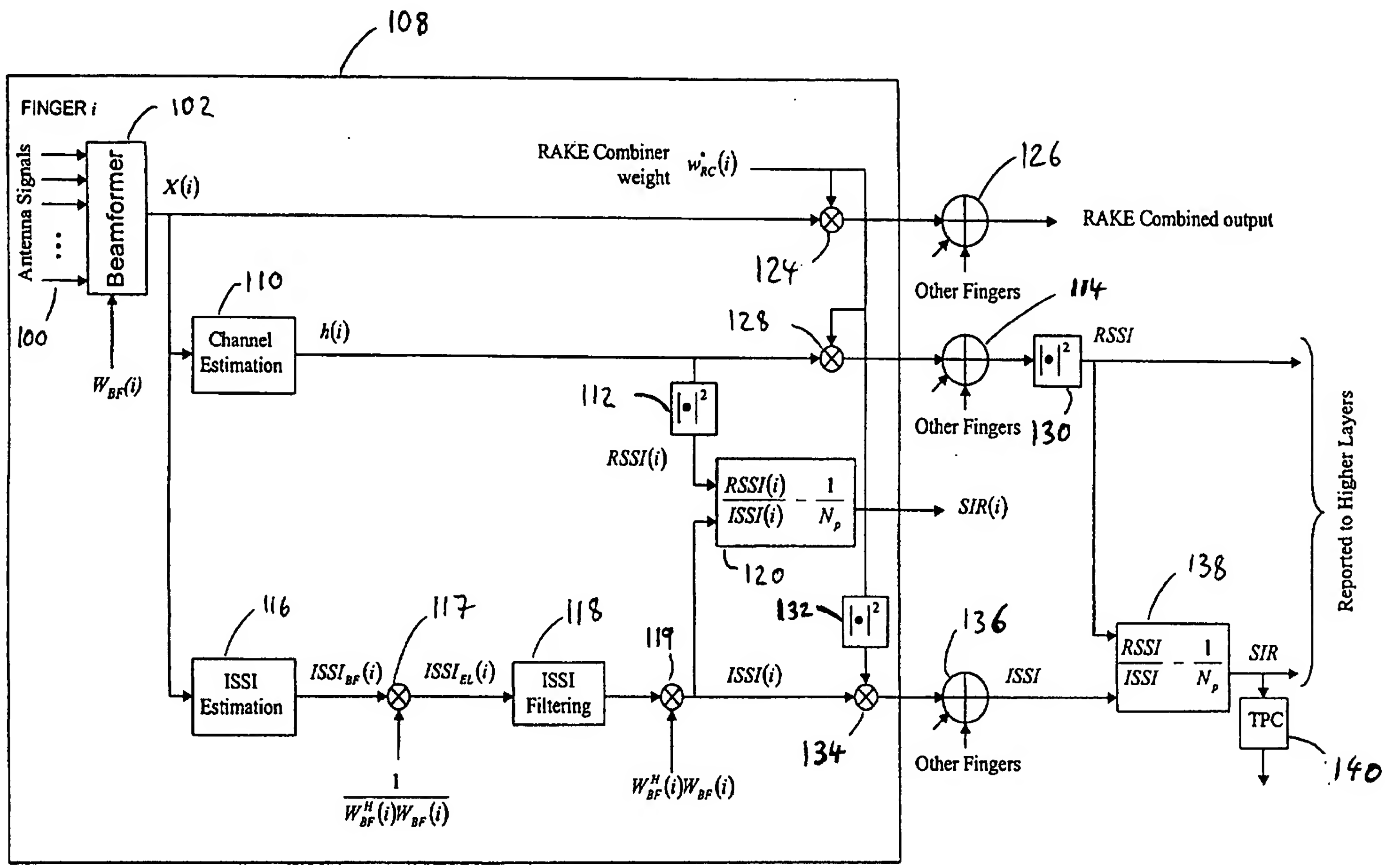

8
FINGER i
10
Channel Estimation
$h(i)$
12
$|\bullet|^2$
$RSSI(i)$
Other Fingers
14
$RSSI$
Reported to higher layers
ISSI Estimation
16
$ISSI_{EL}(i)$
ISSI Filtering
18
$ISSI(i)$
$\frac{RSSI(i)}{ISSI(i)} - \frac{1}{N_p}$
20
$SIR(i)$
22
SIR
Reported to higher layers and used for TPC
Other Fingers
RAKE Combiner weight $w^*_{RC}(i)$
Antenna Signal
$X(i)$
24
26
RAKE Combined output
Other Fingers

FIG. 1



108
FINGER i
102
Antenna Signals
Beamformer
100
$W_{BF}(i)$
$X(i)$
110
Channel Estimation
$h(i)$
RAKE Combiner weight
$w^*_{RC}(i)$
124
128
112
$RSSI(i)$
$\frac{RSSI(i)}{ISSI(i)} - \frac{1}{N_p}$
120
$SIR(i)$
132
116
ISSI Estimation
$ISSI_{BF}(i)$
117
$ISSI_{EL}(i)$
$\frac{1}{W^H_{BF}(i)W_{BF}(i)}$
118
ISSI Filtering
119
$W^H_{BF}(i)W_{BF}(i)$
$ISSI(i)$
134
126
RAKE Combined output
Other Fingers
114
RSSI
130
Other Fingers
136
ISSI
Other Fingers
138
$\frac{RSSI}{ISSI} - \frac{1}{N_p}$
SIR
TPC
140
Reported to Higher Layers

FIG. 2

Receiver and Method of Operation Thereof

The present invention relates to a receiver and a method of operation of the receiver. It finds particular application in RAKE receivers (used in, for example, CDMA), in particular Smart Antenna RAKE receivers having a beamformer. However, the invention is not restricted to such applications but can be used with other receiver architectures, in particular receiver architectures which involve (preferably linear) combining stages, for example Multi-User Detection or Interference Canceller receivers. However, for reasons of simplicity the invention will be described with specific reference to RAKE receivers.

For a better understanding of the invention, certain aspects of the operating principle of an earlier version of a RAKE receiver (hereinafter referred to as "the earlier (RAKE) receiver") will now be described, with reference to Fig. 1. For the avoidance of doubt, this description is not intended to imply that the earlier RAKE receiver forms part of the state of the art.

In the earlier RAKE receiver consisting of N_f fingers the following quantities are estimated in each radio slot:

$h(i)$: This is an estimate of the complex fading channel amplitude for finger i. The quantity $h(i)$ is used to determine the weights for RAKE combining, and to determine $RSSI(i)$ (see below).

$RSSI(i)$: This is the Received Signal Strength Indicator (RSSI) for finger i and represents an estimate of the power of the wanted signal (as opposed to interference or noise). In the earlier RAKE receiver, this is used to calculate $SIR(i)$ (see below).

$ISSI(i)$: This is the Interference Signal Strength Indicator (ISSI) for finger i and represents an estimate of the power of the noise and interference signals. In the earlier RAKE receiver this is used to calculate $SIR(i)$ and may, where Maximum Ratio Combining (MRC) is employed, also be used to calculate the weights for RAKE combining according to the MRC criteria.

$SIR(i)$: This is an estimate of the Signal to Interference Ratio for finger i.

SIR: This is an estimate of the total Signal to Interference Ratio, i.e. after RAKE combining. This is required for transmit power control (TPC) and soft handover combining.

RSSI: This is an estimate of the total RSSI, i.e. after RAKE combining. This quantity is reported to higher layers.

Let $\boldsymbol{X}_i = [x(i,0) \quad x(i,1) \quad \ldots \quad x(i,N_p - 1)]$ be a vector containing the N_p complex valued received known pilot symbols in a given time slot for finger i.

Let $\boldsymbol{D}$ be a 1-by-N_p vector of the known pilot symbols. Each entry in $\boldsymbol{D}$ is $\pm\sqrt{-1}$, so $\boldsymbol{D}\boldsymbol{D}^H = N_p$.

For each RAKE finger i ($0 \leq i \leq N_f - 1$) the following quantities are calculated for each slot (details shown within processing unit 8 relate to finger i only; equivalent processing is carried out for other fingers):

A channel estimate, $h(i) = \frac{1}{N_p} \boldsymbol{X}_i \boldsymbol{D}^H$, estimated by channel estimator 10;

An RSSI estimate, $RSSI(i) = |h(i)|^2$, estimated by RSSI estimator 12, based on the channel estimate *h(i)*;

An ISSI estimate, $ISSI_{EL}(i) = \frac{1}{(N_p - 1)} (\boldsymbol{X}_i - h(i)\boldsymbol{D})(\boldsymbol{X}_i - h(i)\boldsymbol{D})^H$, estimated by ISSI estimator 16, wherein the index "EL" indicates that the relevant quantity is related to a single antenna element. The ISSI estimate is the sample variance of the received symbols (after correcting for the phase reversals due to the known pilot symbols). With the earlier RAKE receiver it is assumed that the power of the ISSI signal is quasi-stationary, and so the ISSI estimate can be filtered, at ISSI filter 18, in order to reduce its variance, to produce ISSI(i). This is done to reduce the variance of the SIR estimate, so as to improve the TPC performance. The exact method of filtering is not critical here, except that the filter should provide an unbiased estimate of the ISSI power. The filtered ISSI estimate is denoted *ISSI*(*i*).

Assume that X_i is of the following form: $X_i \; = \; A_i D \; + \; N_i$.

Here A_i is the complex valued amplitude of the wanted signal and the ISSI signal N_i is a 1-by-N_p vector of noise plus interference samples which is assumed to be white and of power σ_i^2, i.e. $E\{N_i^H N_i\} = \sigma_i^2 I$. Under these assumptions it can be shown that

$$E\{RSSI(i)\} = |A_i|^2 + \frac{\sigma_i^2}{N_p}, \text{ and}$$

$$E\{ISSI(i)\} \; = E\{ISSI_{EL}(i)\} = \; \sigma_i^2$$

where E{} denotes expected value. So *ISSI(i)* is an unbiased estimate of σ_i^2 and *RSSI(i)* is a biased estimate of the wanted signal power. Therefore the SIR can be estimated as follows

$SIR(i) = \dfrac{RSSI(i)}{ISSI(i)} - \dfrac{1}{N_p}$. This calculation is carried out at Finger SIR estimator 20 in Fig. 1.

In order to RAKE combine the antenna signals X_i, for each finger the multiplier 24 multiplies the antenna signal X_i with the respective RAKE Combiner weight $w^*_{RC}(i)$, and the thus weighted signals are added by adder 26 so as to produce the RAKE Combined output signal.

With the earlier RAKE receiver the (reasonable) assumption is made that the ISSI signals on each RAKE finger are uncorrelated. The RAKE combined SIR is then estimated, at adder 22, by summing the finger SIRs, i.e.

$$SIR = \sum_{i=0}^{N_f - 1} SIR(i).$$

Likewise, the RAKE combined RSSI is estimated by adder 14 by summing the finger RSSIs, i.e.

$$RSSI = \sum_{i=0}^{N_f - 1} RSSI(i)$$

Whilst the above assumptions are reasonable and the above method works satisfactorily in many situations, the present inventor has appreciated that there are cases in which the SIR measurement scheme described above cannot be applied or will provide unsatisfactory results.

In a first method aspect, the present invention provides a method of estimating an Interference Signal Strength Indicator (ISSI) for a finger in a receiver which receiver is arranged to combine signals from a plurality of antenna elements to provide a formed signal, the method comprising:

estimating the ISSI for the formed signal; and

filtering the estimated ISSI to obtain a filtered estimate of ISSI;

wherein, prior to filtering, the estimate of ISSI is pre-processed based on weighting factors used in the combiner to obtain an estimate of ISSI representative of ISSI for the antenna elements; and, subsequent to filtering, the filtered estimate of ISSI is post-processed based on weighting factors used in the combiner to provide a filtered estimate of ISSI for the formed signal.

This has the advantage that the filtering relates more directly to the actual antenna signals and, in particular, allows changes in weighting factors which are significant in the time scale of the filter to be compensated for whilst still providing an estimate of ISSI for the formed signal.

Preferably, the post-processing is the inverse of the pre-processing.

Further preferably, the pre-processing comprises dividing by the squared norm of the weight vector used in the combiner.

Preferably, the receiver is arranged to combine linearly the signals from the plurality of antenna elements to provide the formed signal.

Thus, whilst on first sight it may seem that the pre-processing and the post-processing merely cancel each other out and could therefore be omitted (at least in the case of one being the inverse of the other), surprisingly this is not so. The pre-processing and the post-processing is

carried out so as to take into account the fact that the weightings of the (linear) combiner may vary faster than the filtering, and, at least partially, to compensate for this fact.

In a first apparatus aspect corresponding to the first method aspect the present invention also provides apparatus for estimating an Interference Signal Strength Indicator (ISSI) for a finger in a receiver which receiver is arranged to combine signals from a plurality of antenna elements to provide a formed signal, the apparatus comprising:

means for estimating the ISSI for the formed signal; and

means for filtering the estimated ISSI to obtain a filtered estimate of ISSI;

wherein the apparatus further comprises means for pre-processing, prior to filtering, the estimate of ISSI, based on weighting factors used in the combiner to obtain an estimate of ISSI representative of ISSI for the antenna elements; and means for post-processing, subsequent to filtering, the filtered estimate of ISSI, based on weighting factors used in the combiner to provide a filtered estimate of ISSI for the formed signal.

An implementation of the first apparatus aspect provides a receiver comprising

a combiner for combining signals from a plurality of antenna elements to provide a formed signal;

an ISSI estimator for estimating the ISSI for the formed signal;

a divider for dividing the ISSI estimate by the squared norm of the weight vector used in the combiner to provide an estimate of ISSI representative of ISSI for the antenna elements;

a filter for filtering the estimate of ISSI representative of ISSI for the antenna elements to provide a filtered estimate of ISSI; and

a multiplier for multiplying the filtered ISSI estimate by the squared norm of the weight vector used in the combiner to provide a filtered estimate of ISSI for the formed signal.

In a related, second method aspect, the present invention provides a method of estimating the total Received Signal Strength Indicator (RSSI) for a receiver which receiver is arranged to combine signals from a plurality of antenna elements, the method comprising:

coherently summing the channel estimates $h(i)$ for each finger of the receiver to provide a coherent sum; and

calculating the magnitude of the coherent sum.

Coherently summing the channel estimates $h(i)$ for each finger in a receiver which is arranged to combine the signals from a plurality of antenna elements may result in more accurate estimation of the RSSI for the receiver than simple scalar summing, as is done in the earlier receiver. This is particularly important if an algorithm other than MRC is used to combine the (RAKE) finger signals.

The total RSSI may advantageously be used to estimate total SIR.

In a second apparatus aspect the present invention also provides apparatus for estimating the total Received Signal Strength Indicator (RSSI) for a receiver which receiver is arranged to combine signals from a plurality of antenna elements, the apparatus comprising:

means for coherently summing the channel estimates $h(i)$ for each finger of the receiver to provide a coherent sum; and

means for calculating the magnitude of the coherent sum.

A receiver implementing this apparatus may be provided as set out in Claim 22.

In a related, third method aspect, the present invention provides a method of estimating the total Signal to Interference Ratio (SIR) in a receiver which receiver has a plurality of fingers and is arranged to combine signals from a plurality of antenna elements, each finger having interference characteristics from which an SIR for each finger is determined, the method comprising:

estimating the total SIR for the receiver from the total Received Signal Strength Indicator (RSSI) for the receiver and the total Interference Signal Strength Indicator (ISSI) for the receiver and not from summing individual SIRs for each finger.

This aspect stems from the appreciation by the inventor that the Combined SIR may not equal the sum of the finger SIRs, particularly when MRC is not used.

Preferably, RSSI is calculated in accordance with the second aspect.

In a third apparatus aspect the present invention also provides apparatus for estimating the total Signal to Interference Ratio (SIR) in a receiver which receiver has a plurality of fingers

and is arranged to combine signals from a plurality of antenna elements, each finger having interference characteristics from which an SIR for each finger is determined, the apparatus comprising:

means for estimating the total SIR for the receiver from the total Received Signal Strength Indicator (RSSI) for the receiver and the total Interference Signal Strength Indicator (ISSI) for the receiver and not from summing individual SIRs for each finger.

A receiver implementing this apparatus aspect may also be provided.

Accurate estimation of SIR for a receiver having multiple fingers is particularly important when the SIR is used for transmit power control. Hence, in a related, fourth aspect, the present invention provides a method of controlling the transmit power in a receiver which receiver has a plurality of fingers and is arranged to combine signals from a plurality of antenna elements, the method comprising:

estimating the total SIR for the receiver in accordance with the third method aspect; and

using the estimated SIR for controlling the transmit power.

In a fourth apparatus aspect the present invention also provides a receiver having a plurality of fingers and being arranged to combine signals from a plurality of antenna elements, the receiver comprising:

apparatus in accordance with the third apparatus aspect; and

means for controlling the transmit power using the estimated SIR..

A receiver comprising this apparatus is also provided.

Whilst in the earlier receiver it was not proposed to calculate a total ISSI for the receiver, it has been found that this may be of use, pursuant to a fifth aspect of the invention, for example for the estimation of the total Signal to Interference Ratio (SIR). Hence, in the fifth aspect, the present invention provides a method of estimating the total Interference Signal Strength Indicator (ISSI) for a receiver for use in the estimation of the total Signal to Interference Ratio (SIR) in the receiver, the receiver having a plurality of fingers and being arranged to combine signals from a plurality of antenna elements,

the method comprising:

estimating the total ISSI as a function of the individual ISSIs for each finger.

In a fifth apparatus aspect the present invention also provides apparatus for estimating the total Interference Signal Strength Indicator (ISSI) for a receiver for use in the estimation of the total Signal to Interference Ratio (SIR) in the receiver, the receiver having a plurality of fingers and being arranged to combine signals from a plurality of antenna elements,

the apparatus comprising:

means for estimating the total ISSI as a function of the individual ISSIs for each finger.

A receiver comprising this apparatus is also provided.

Features of the various aspects of the invention can be implemented in hardware or software, or a combination of both, as will be clear to one skilled in the art.

The invention also provides a computer or integrated circuit programmed so as to carry out any of the method(s) described above, and a computer program for causing a computer to carry out any of the method aspects.

The advantages of the present invention are particularly applicable to a Smart Antenna RAKE receiver. By way of explanation, in a Smart Antenna RAKE receiver the input to each RAKE finger is not a single antenna signal but the output of a beamformer (BF). The BF performs a linear combination of N_e antenna signals, using a N_e-by-1 time varying vector of beamformer weights, W_{BF}. The resulting finger signals are often, but not necessarily, combined using MRC (as an alternative, for example, a minimum mean squared error algorithm may be used).

In a Smart Antenna receiver, problems caused by the fact that the ISSI may not be stationary could be alleviated if the BF algorithm is arranged to allow only slow changes in the BF weight vector, since in this case the BF output ISSI can be assumed to be quasi-stationary. However it has been appreciated that this is in general undesirable, because it will limit the ability of the BF algorithm to track changes in the signal environment. Aspects of the invention overcome this problem.

In a Smart Antenna receiver, problems caused by the fact that the ISSI may not be stationary could be alleviated if the BF algorithm is arranged to allow only slow changes in the BF weight vector, since in this case the BF output ISSI can be assumed to be quasi-stationary. However it has been appreciated that this is in general undesirable, because it will limit the ability of the BF algorithm to track changes in the signal environment. Aspects of the invention overcome this problem.

As indicated above, problems akin to those described above may also occur in other receiver architectures that involve combining stages, in particular those with linear combiners, for example Multi-User Detection or Interference Canceller receivers. It will be clear to one skilled in the art, in the light of the following description of one embodiment of the present invention, how the novel techniques which have been illustrated with reference to a Smart Antenna RAKE Receiver can be applied to such other receiver structures, *mutatis mutandis*.

Preferred features of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 schematically shows certain components of an earlier RAKE receiver; and

Fig. 2 schematically shows apparatus according to an embodiment of the present invention.

Details of Fig. 1 have already been described above. Parts of Fig. 2 are similar to corresponding parts of Fig. 1, and perform similar functions. In particular, *h*(*i*) (estimated by channel estimator 110), *RSSI*(*i*) (estimated by RSSI Estimator 112) and the RAKE combined output signal (produced by multiplier 124 and adder 126) are calculated exactly as described above for the earlier RAKE receiver, and a detailed description thereof will not be repeated here. However, Whilst X_i denoted the antenna signal in Fig. 1, in Fig. 2 it denotes the output of the beamformer 102 (BF), which generates the formed beam signal X_i from a plurality of antenna signals 100. Further, as mentioned above, the finger signals may be RAKE combined using a technique other than MRC.

In Fig. 2, the contents of processing unit 108 relate to Finger *i* only. Equivalent processing is performed for other fingers.

Pursuant to the invention it has now been appreciated that, in order to address problems related to the fact that the ISSI may not be quasi-stationary, it can be assumed that the mean power of the ISSI signal at each antenna element is the same. This is a reasonable assumption for the type of antenna configurations typically considered for Smart Antenna deployments.

It has further been appreciated that it can be of advantage to assume that the ISSI signals at each antenna element are uncorrelated. This is a reasonable assumption and becomes more accurate in the case that the number of interference signals is large, such as in a WCDMA cell serving a large number of voice users.

Making use of these assumptions, in Fig. 2, multiplier 119 multiplies the filtered ISSI at each antenna element, $ISSI_{EL}$, with the squared norm of the weight vector used during that slot, $W_{BF}^{H}(i)W_{BF}(i)$, to estimate the Finger ISSI, i.e.

$$ISSI(i) = \left(W_{BF}^{H}(i)W_{BF}(i)\right)ISSI_{EL}(i).$$

The BF output ISSI is estimated by ISSI estimator 116 each slot exactly as in the standard RAKE receiver case, as follows

$$ISSI_{BF}(i) = \frac{1}{\left(N_p - 1\right)}\left(X_i - h(i)D\right)\left(X_i - h(i)D\right)^H.$$

However, ISSI filtering is not directly performed on the BF output ISSI. Instead, $ISSI_{BF}(i)$ is divided by divider 117 by the squared norm of the weight vector used during that slot, $W_{BF}^{H}(i)W_{BF}(i)$. The resulting signal $ISSI_{EL}(i)$ undergoes ISSI filtering at ISSI filter 118, and subsequently the squared weight vector norm is reapplied by multiplier 119, as mentioned above, to obtain $ISSI(i)$.

Although the estimation of the RAKE combined SIR does not require each finger SIR to be estimated, an estimate of the finger SIR, $SIR(i)$, can nevertheless be calculated by Finger SIR estimator 120 from $RSSI(i)$ and $ISSI(i)$, if required, just as in the earlier RAKE receiver. However, the Finger SIR is not used to determine the total SIR.

It can further be assumed that the ISSI signals are uncorrelated between RAKE fingers. This assumption was also made in the case of the earlier RAKE receiver.

The RSSI after RAKE combining is calculated by coherently combining the channel estimates, as follows (this is correct for any set of RAKE combiner weights $w_{RC}(i)$, and therefore applies to any combining algorithm). For each finger, the channel estimate $h(i)$ is multiplied by multiplier 128 with the relevant RAKE Combiner weight $w^{*}_{RC}(i)$. Adder 114 then sums these weighted estimates, and RSSI estimator 130 calculates the square of the absolute value of this sum, i.e.

$$RSSI = \left| \sum_{i=0}^{N_f-1} w_{RC}^{*}(i) h(i) \right|^2$$

Using the assumption that the ISSI signals are uncorrelated between RAKE fingers, the ISSI after RAKE combining is found, pursuant to the invention, by power summation of the finger ISSIs, as shown at 132, 134, 136. Multiplier 134 multiplies the finger ISSI with the square (formed by processing unit 132) of the RAKE Combiner weight $w_{RC}(i)$. Adder 136 sums the results of this multiplication obtained for each finger. In mathematical terms:

$$ISSI = \sum_{i=0}^{N_f-1} \left| w_{RC}(i) \right|^2 ISSI(i).$$

Further pursuant to the invention, the RAKE Combined SIR is then estimated by SIR estimator 138 as follows.

$$SIR = \frac{RSSI}{ISSI} - \frac{1}{N_p}.$$

The RAKE Combined SIR can then be used by transmit power controller 140, for transmit power control. It can also be reported to higher layers of the receiver architecture. Likewise, the total RSSI can be reported to higher layers.

While the present invention has been described in its preferred embodiments, it is to be understood that the words which have been used are words of description rather than limitation and that changes may be made to the invention without departing from its scope as defined by the appended claims.

Each feature disclosed in this specification (which term includes the claims) and/or shown in the drawings may be incorporated in the invention independently of other disclosed and/or illustrated features.

CLAIMS:

1. A method of estimating an Interference Signal Strength Indicator (ISSI) for a finger in a receiver which receiver is arranged to combine signals from a plurality of antenna elements to provide a formed signal, the method comprising:

estimating the ISSI for the formed signal; and

filtering the estimated ISSI to obtain a filtered estimate of ISSI;

wherein, prior to filtering, the estimate of ISSI is pre-processed based on weighting factors used in the combiner to obtain an estimate of ISSI representative of ISSI for the antenna elements; and, subsequent to filtering, the filtered estimate of ISSI is post-processed based on weighting factors used in the combiner to provide a filtered estimate of ISSI for the formed signal.

2. A method according to Claim 1, wherein the post-processing is the inverse of the pre-processing.

3. A method according to Claim 1 or Claim 2, wherein the pre-processing comprises dividing by the squared norm of the weight vector used in the combiner.

4. A method according to any of Claims 1 to 3, wherein the receiver is arranged to combine linearly the signals from the plurality of antenna elements to provide the formed signal.

5. A method according to any of Claims 1 to 4, wherein the receiver is a RAKE receiver, preferably a Smart Antenna RAKE receiver.

6. A method according to any of Claims 1 to 5, wherein the signals from the plurality of antenna elements are combined by means of a beamformer.

7. Apparatus for estimating an Interference Signal Strength Indicator (ISSI) for a finger in a receiver which receiver is arranged to combine signals from a plurality of antenna elements to provide a formed signal, the apparatus comprising:

means for estimating the ISSI for the formed signal; and

means for filtering the estimated ISSI to obtain a filtered estimate of ISSI;

wherein the apparatus further comprises means for pre-processing, prior to filtering, the estimate of ISSI, based on weighting factors used in the combiner to obtain an estimate of ISSI representative of ISSI for the antenna elements; and means for post-processing, subsequent to filtering, the filtered estimate of ISSI, based on weighting factors used in the combiner to provide a filtered estimate of ISSI for the formed signal.

8. Apparatus according to Claim 7, wherein the post-processing means is configured to carry out an operation which is the inverse of an operation which the pre-processing means is configured to carry out.

9. Apparatus according to Claim 7 or Claim 8, wherein the pre-processing means comprises means for dividing the estimate of ISSI by the squared norm of the weight vector used in the combiner, prior to filtering.

10. A receiver comprising

a combiner for combining signals from a plurality of antenna elements to provide a formed signal; and

apparatus according to any of Claims 7 to 9.

11. A receiver according to Claim 10, wherein the combiner is arranged to combine linearly the signals from the plurality of antenna elements to provide the formed signal.

12. A receiver according to Claim 10 or Claim 11, comprising a RAKE receiver, preferably a Smart Antenna RAKE receiver.

13. A receiver according to any of Claims 10 to 12, wherein the combiner comprises a beamformer.

14. A receiver comprising

a combiner for combining signals from a plurality of antenna elements to provide a formed signal;

an ISSI estimator for estimating the ISSI for the formed signal;

a divider for dividing the ISSI estimate by the squared norm of the weight vector used in the combiner to provide an estimate of ISSI representative of ISSI for the antenna elements;

a filter for filtering the estimate of ISSI representative of ISSI for the antenna elements to provide a filtered estimate of ISSI; and

a multiplier for multiplying the filtered ISSI estimate by the squared norm of the weight vector used in the combiner to provide a filtered estimate of ISSI for the formed signal.

15. A method of estimating the total Received Signal Strength Indicator (RSSI) for a receiver which receiver is arranged to combine signals from a plurality of antenna elements, the method comprising:

coherently summing the channel estimates $h(i)$ for each finger of the receiver to provide a coherent sum; and

calculating the magnitude of the coherent sum.

16. A method according to Claim 15, further comprising squaring said magnitude.

17. A method according to Claim 15 or 16, wherein the receiver is arranged to combine linearly the signals from the plurality of antenna elements.

18. A method according to any of Claims 15 to 16, wherein the receiver is a RAKE receiver, preferably a Smart Antenna RAKE receiver.

19. A method according to Claim 18, wherein coherently summing the channel estimates $h(i)$ for each finger of the receiver comprises

weighting the channel estimates with the RAKE Combiner weight of the respective finger; and

adding the weighted channel estimates.

20. Apparatus for estimating the total Received Signal Strength Indicator (RSSI) for a receiver which receiver is arranged to combine signals from a plurality of antenna elements, the apparatus comprising:

means for coherently summing the channel estimates $h(i)$ for each finger of the receiver to provide a coherent sum; and

means for calculating the magnitude of the coherent sum.

21. Apparatus according to Claim 20, further comprising means for squaring said magnitude.

22. A receiver comprising

a combiner for combining signals from a plurality of antenna elements to provide a formed signal; and

apparatus according to Claim 20 or Claim 21.

23. A receiver according to Claim 22, wherein the combiner is arranged to combine linearly the signals from the plurality of antenna elements.

24. A receiver according to Claim 22 or Claim 23, comprising a RAKE receiver, preferably a Smart Antenna RAKE receiver.

25. A receiver according to any of Claims 22 to 24, wherein the means for coherently summing the channel estimates $h(i)$ for each finger of the receiver comprises

means for weighting the channel estimates with the RAKE Combiner weight of the respective finger; and

means for adding the weighted channel estimates.

26. A method of estimating the total Signal to Interference Ratio (SIR) in a receiver which receiver has a plurality of fingers and is arranged to combine signals from a plurality of antenna elements, each finger having interference characteristics from which an SIR for each finger is determined, the method comprising:

estimating the total SIR for the receiver from the total Received Signal Strength Indicator (RSSI) for the receiver and the total Interference Signal Strength Indicator (ISSI) for the receiver and not from summing individual SIRs for each finger.

27. A method according to Claim 26, wherein the receiver is arranged to combine linearly the signals from the plurality of antenna elements.

28. A method according to Claim 26 or Claim 27, wherein the receiver is a RAKE receiver, preferably a Smart Antenna RAKE receiver.

29. A method according to any of Claims 26 to 28, wherein the signals from the plurality of antenna elements are combined by means of a beamformer.

30. A method according to any of Claims 26 to 29, wherein the SIR for each finger is made available, but not used for estimation of the total SIR.

31. A method according to any of Claims 26 to 30, wherein the total ISSI for the receiver is obtained as a function of the finger ISSIs estimated according to any of Claims 1 to 6.

32. A method according to any of Claims 26 to 31, wherein the total RSSI for the receiver is estimated according to any of Claims 15 to 19.

33. Apparatus for estimating the total Signal to Interference Ratio (SIR) in a receiver which receiver has a plurality of fingers and is arranged to combine signals from a plurality of antenna elements, each finger having interference characteristics from which an SIR for each finger is determined, the apparatus comprising:

means for estimating the total SIR for the receiver from the total Received Signal Strength Indicator (RSSI) for the receiver and the total Interference Signal Strength Indicator (ISSI) for the receiver and not from summing individual SIRs for each finger.

34. Apparatus according to Claim 33, further comprising means for estimating the SIR for each finger.

35. Apparatus according to Claim 33 or Claim 34, further comprising apparatus according to any of Claims 7 to 9.

36. Apparatus according to any of Claims 33 to 35, further comprising apparatus according to Claim 20 or Claim 21.

37. A receiver comprising

a combiner for combining signals from a plurality of antenna elements to provide a formed signal; and

apparatus according to any of Claims 33 to 36.

38. A receiver according to Claim 37, wherein the combiner is arranged to combine linearly the signals from the plurality of antenna elements.

39. A receiver according to Claim 37 or Claim 38, comprising a RAKE receiver, preferably a Smart Antenna RAKE receiver.

40. A receiver according to any of Claims 37 to 39, wherein the combiner comprises a beamformer.

41. A method of controlling the transmit power in a receiver which receiver has a plurality of fingers and is arranged to combine signals from a plurality of antenna elements, the method comprising:

estimating the total SIR for the receiver according to any of Claims 26 to 32; and

using the estimated SIR for controlling the transmit power.

42. A receiver having a plurality of fingers and being arranged to combine signals from a plurality of antenna elements, the receiver comprising:

apparatus according to any of Claims 33 to 36; and

means for controlling the transmit power using the estimated SIR.

43. A method of estimating the total Interference Signal Strength Indicator (ISSI) for a receiver for use in the estimation of the total Signal to Interference Ratio (SIR) in the receiver, the receiver having a plurality of fingers and being arranged to combine signals from a plurality of antenna elements,

the method comprising:

estimating the total ISSI as a function of the individual ISSIs for each finger.

44. A method according to Claim 43, wherein the receiver is arranged to combine linearly the signals from the plurality of antenna elements.

45. A method according to Claim 43 or Claim 44, wherein the receiver is a RAKE receiver, preferably a Smart Antenna RAKE receiver.

46. A method according to Claim 45, wherein estimating the total ISSI comprises

multiplying, for each finger, the individual ISSI for that finger with the square of the absolute value of the RAKE Combiner weight for that finger, and

summing these products.

47. A method according to any of Claims 43 to 46, wherein the signals from the plurality of antenna elements are combined by means of a beamformer.

48. Apparatus for estimating the total Interference Signal Strength Indicator (ISSI) for a receiver for use in the estimation of the total Signal to Interference Ratio (SIR) in the receiver, the receiver having a plurality of fingers and being arranged to combine signals from a plurality of antenna elements,

the apparatus comprising:

means for estimating the total ISSI as a function of the individual ISSIs for each finger.

49. A receiver comprising

a combiner for combining signals from a plurality of antenna elements to provide a formed signal; and

apparatus according to Claim 48.

50. A receiver according to Claim 49, wherein the combiner is arranged to combine linearly the signals from the plurality of antenna elements.

51. A receiver according to Claim 49 or Claim 50, comprising a RAKE receiver, preferably a Smart Antenna RAKE receiver.

52. A receiver according to Claim 51, wherein the means for estimating the total ISSI comprises

means for multiplying, for each finger, the individual ISSI for that finger with the square of the absolute value of the RAKE Combiner weight for that finger, and

means for summing these products.

53. A receiver according to any of Claims 49 to 52, wherein the combiner comprises a beamformer.

54. A computer or integrated circuit programmed so as to carry out the method of any of Claims 1 to 6, 15 to 19, 26 to 32, 41 or 43 to 47.

55. A computer program for causing a computer to carry out the method of any of Claims 1 to 6, 15 to 19, 26 to 32, 41 or 43 to 47.

56. A method, apparatus, receiver, computer or computer program substantially as herein described with reference to, or as illustrated in Fig. 2 of the accompanying drawings.

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Application No: GB 0104976.6
Claims searched: 1-14

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Examiner: Gareth Griffiths
Date of search: 5 July 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): H4L (LDDRCW, LDDRCX, LDDRX, LERX), H4P (PAN)

Int Cl (Ed.7): H04B 1/10, 1/707, 7/08

Other: Online Databases: WPI, EPODOC, JAPIO, INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	EP0999652 A1 (LUCENT)	
A, E	WO01/73966 A1 (MATSUSHITA)	

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